Measuring neutrino cross-section with IceCube at intermediate energies (~100 GeV to a few TeV)

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Motivation

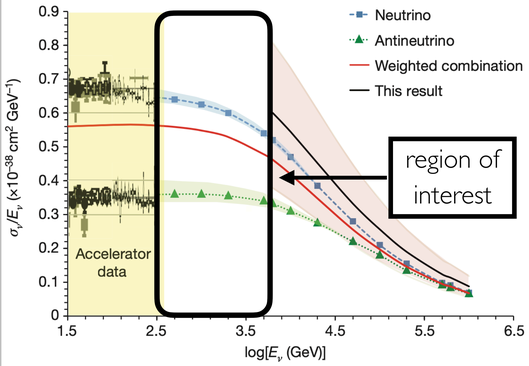


Figure 1: Published measurement of neutrino-nucleon cross-section at high energies [1].

- Neutrino-nucleon cross-sections have been measured at low energies (up to few 100 GeV) by accelerator experiments, and at high energies (few TeV to few PeV) using IceCube data
- Currently, no measurements exist in the transition region. Does the shape match the model?

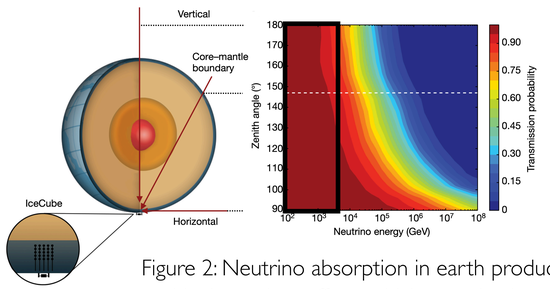


Figure 2: Neutrino absorption in earth produces a strong, zenith-dependent effect at high energies, but a much weaker effect at low energies [1].

- Flux attenuation due to interactions with earth's interior is a relatively small effect below a few TeV
- Expect event rate to scale linearly with cross-section and thus can be measured as the normalization of predicted flux
- Use a pre-existing, high-statistics sample of diffuse muon neutrinos [2]

Event Reconstruction

- In ~100 GeV to ~5 TeV range, muon energy losses transition from minimum ionizing to radiative-loss-dominated → benefit from a unique reconstruction hypothesis
- Approximate the muon track as a series of point-like showers, each with an equal fraction of the total muon energy & use a likelihood-based method to fit energy

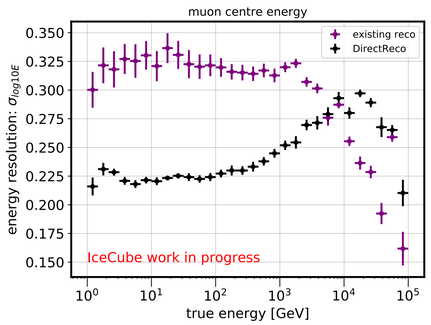
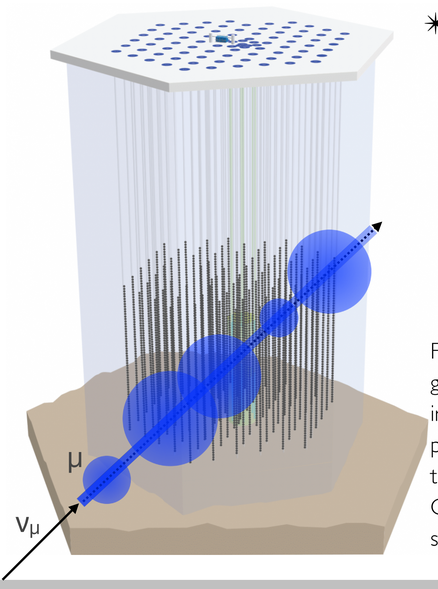


Figure 3: Resolution of energy reconstruction currently in use (purple) and new method described here (black).

- Another challenge is that our most advanced models of the natural glacial medium are too complex to be represented in lookup tables (used for traditional reconstruction methods) → use direct photon propagation to generate event hypotheses (DirectReco)



- Combining the tailored event hypothesis with real-time event simulation generation of hypotheses results in improvement in energy resolution for our target range!

Figure 4: Production of a through-going muon - a muon neutrino interacts outside the IceCube array, producing a daughter muon which traverses the detector, emitting Cherenkov radiation and producing stochastic losses along its path.

Analysis Plans

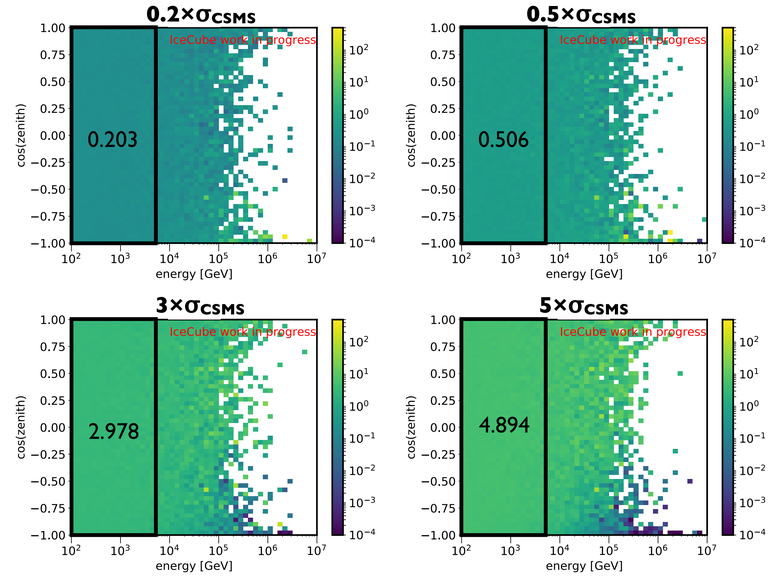


Figure 5: Checking the linearity between event rate/normalization and cross-section. Plots show the ratio of expected events for a modified cross-section (e.g. 0.2*CSMS), divided by expected events for standard CSMS model[3], binned in neutrino energy and zenith angle; mean value of bins in the region of interest is noted. A change in cross-section produces a roughly linear change in expected events, shown here.

- Determine a total flux-dependent neutrino-nucleon cross-section for ~ 100 GeV - 5 TeV with a forward folding analysis
- Update to latest atmospheric flux model predictions [4]
- Explore an energy dependent cross-section measurement with a shape analysis for the flux
- Investigate possibility of neutrino absorption measurement for 1 - 5 TeV

References

[1] M. G. Aartsen et al., Nature 551 (2017) 596-600 .
[2] M. G. Aartsen et al., PoS (ICRC 2019), 1017.
[3] A. Cooper-Sarkar, P. Mertsch, and S. Sarkar, JHEP08 (2011) 042.
[4] A. Fedynitch et al., EPJ Web Conf., 99 (2015) 08001.